New Optics of the LEP Injector Linac for Positron Production

C. Bourat[1], H. Braun, L. Rinolfi
CERN-PS
CH - 1211 Geneva 23

Abstract

In the LEP Injector Linacs (LIL), a new optics has been implemented in order to optimise the positron production. Simulations are mainly based on the TRANSPORT code. The experimental results show an increase of 23 % at the end of LIL compared to the previous best operational values.

1. INTRODUCTION

A new bunching system was installed in 1991 in the LIL machine and performance figures for positrons are reported in [1]. The yield measurement was the only data which provided a figure of merit for the new bunching system. In 1992, a 3 GHz RF deflector was installed at the buncher output and allowed measurements of the micro-bunch length at 4 MeV [2]. Now a Transition-Cherenkov monitor is installed just upstream the positron target and allows measurements of the micro-bunch length of the primary beam at 200 MeV. A new code COMPOST allows the simulation of the positron production and the acceleration up to 90 MeV. Simulation results were compared to experimental values assuming 100 % transmission in the linac. Since a rather good agreement was found a proposal for an improvement of positron capture was made [3]. The positron beam dynamics simulations are performed with TRANSPORT code starting at 90 MeV up to 500 MeV. Finally after the implementation of the new optics a substantial increase of positrons at the end of LIL was measured.

2. SIMULATIONS

2.1. Layout of LIL

Figure 1 gives the LIL layout.

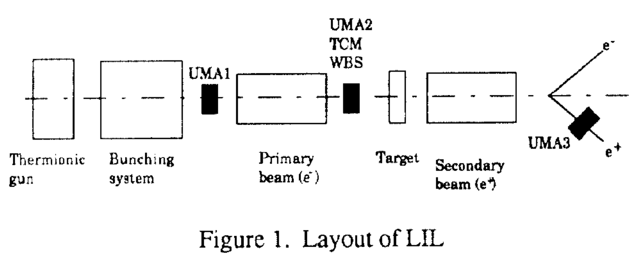

Figure 1. Layout of LIL

The different monitors are UMA (Beam position monitor), TCM (Transition Cherenkov monitor), WBS (Wire beam scanner). The thermionic gun was modelled with the EGUN code. The bunching system was studied and optimised with the PARMELA code [1]. The positron capture is investigated with the COMPOST code [4] and the LIL beam dynamics optimised by the TRANSPORT code.

2.2 Primary beam without beam loading

The primary beam is studied from the buncher output (UMA1) until the positron target (UMA2) with TRANSPORT. The aim is to get 100 % of transmission and find a minimum spot size. Table 1 gives the nominal conditions, at the buncher output, which are used as input data for TRANSPORT.

Table 1
Beam characteristics at the linac input

Half beam size (H,V)	6	mm
Half beam divergence	21	mrad
Geometrical emittance (90%)	76	mm.mrad
Momentum	4.3	MeV/c

Figure 2 shows the beam envelopes between UMA1 and the positron target. After optimisation, the beam spot radius (on the target) is 0.6 mm, for 90 % of particles.

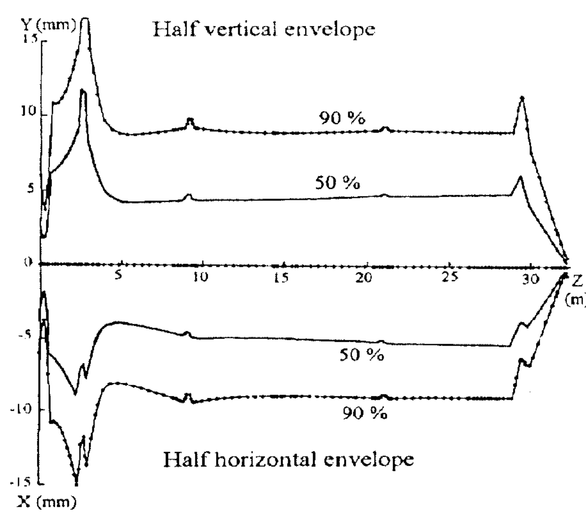

Figure 2. Beam envelopes without beam loading effect

[1] from General Electric Medical Systems

2.3 Primary beam with beam loading

When the primary beam is used at high charge, in the region of 30 nC on the target, the beam loading should be taken into account. Therefore simulations are done with a momentum at the buncher exit varying between 4.1 MeV/c and 4.5 MeV/c. The energy spread at the end of the linac is 28 MeV. For 100 % transmission, the beam radius on the target becomes 1.3 mm (for 90 % of particles).

Figure 3 gives the beam envelopes after optimisation of the optics with loading corresponding to 3 output energies, 190.1 MeV, 204.3 MeV and 218.5 MeV.

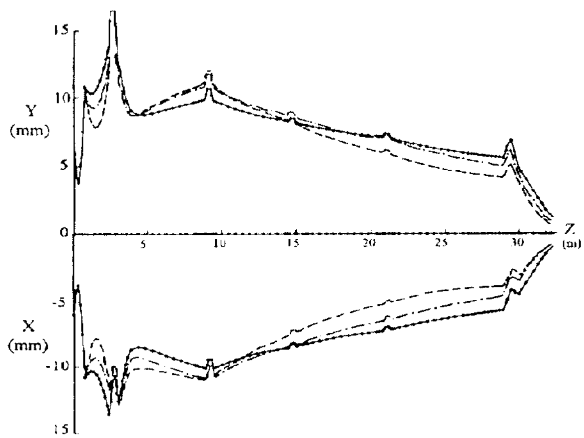

Figure 3. Primary beam envelopes

2.4 Modelized accelerating field

In order to simplify the operation of the machine, all klystron modulators are working with the same output power. The value is 15.5 MW for each klystron. The klystrons equipped with LIPS (LIL Power Saver) [5] feed 4 accelerating sections, those without LIPS feed two accelerating sections. These latter have 7.1 MW at the input coupler and provide a constant accelerating field of 9.2 MV/m which corresponds to an energy gain of 42 MeV per section. The sections with LIPS have the equivalent of 8.8 MW peak power at the input coupler. They provide an accelerating field as shown on figure 4 which produces an energy gain of 44 MeV per section. The final energy at the end of the linac (500 MeV) is tuned by timing adjustment of the LIPS phase inversion.

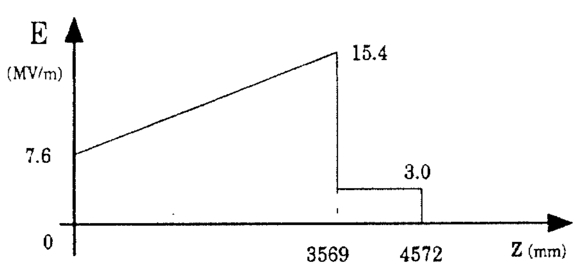

Figure 4. Electric field shape in accelerating sections with LIPS

2.5 Secondary beam

The positrons are generated in a 2-radiation-length tungsten target and are focused by a 44 mm long pulsed solenoid into the accelerating RF structure. The peak magnetic field is 0.83 T. The first two sections of the positron linac are embedded in a long DC solenoid field of 0.36 T [3]. The positron production in the target is simulated with GEANT. COMPOST is used to compute the particle trajectories from the target to the end of the first two travelling-wave sections downstream of the target. COMPOST is a multi-particle tracking code with emphasis on positron capture optics. It uses a Runge-Kutta integration method with adaptive step-size to solve the equations of motion.

The COMPOST output data are given in table 2. The 90 MeV energy corresponds to two accelerating sections (without LIPS) plus the positron energy at the target exit. Since the charge is very low the beam loading for the positron beam is negligible.

Table 2
Positron beam characteristics downstream from the first two accelerating sections

Energy	90 MeV
Half beam size	10.5 mm
Half beam divergence	6 mrad
Energy spread	± 7 %
Geometrical emittance (100%)	62 π mm.mrad

Figure 5 shows the beam envelopes starting from 90 MeV up to 500 MeV, after optimisation with the modified version of TRANSPORT [6]. The half envelopes are plotted together with the aperture of all accelerating sections (ACS 27 to 36). Only in two points is the envelope cut by the accelerating section aperture. The Twiss parameters are determined at the end of LIL and allow the optimisation of the matching to the accumulator.

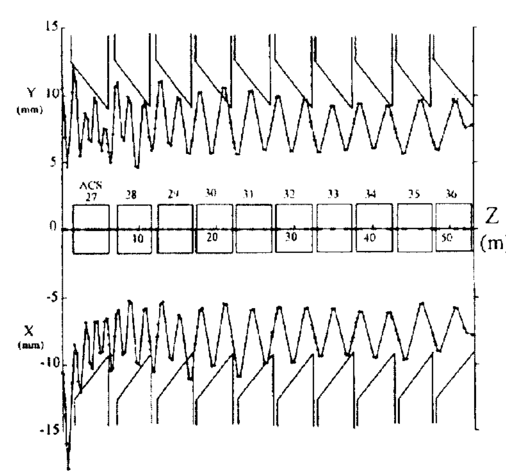

Figure 5. Beam envelopes with the new optics

3. EXPERIMENTAL RESULTS

3.1 Micro-bunch length

Figure 6 shows a micro-bunch measurement done with the TCM. The light is analysed in a streak camera. The pulse length is 14 ps (FWHH). It has to be compared to the design value of 16 ps computed from PARMELA code. The distance between bunches is 333 ps corresponding to the 2.99855 GHz of the linac.

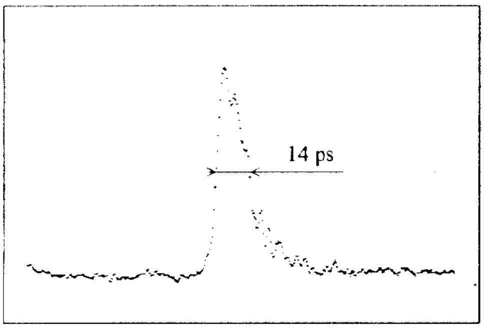

Figure 6. Micro-bunch length at 200 MeV

3.2 Emittances of positron beam

The beam emittances were measured with the three gradients method at 500 MeV. The measured values for geometrical emittances (90 %) are 5.5 π mm.mrad in both planes. It is somewhat less than the calculated COMPOST emittance.

3.3 Energy spectrum for positrons

Close to UMA3, a secondary emission monitor allows us to measure the energy spectrum. Figure 7 gives the profile obtained with the new optics. The accumulator acceptance being ± 1 % in energy, there will be 78 % of positrons captured.

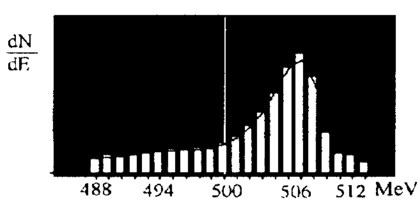

Figure 7. Spectrum of positron at 500 MeV

4. LIL PERFORMANCE

A set of measured performance values is given in table 3. The normalised yield is defined as the number of positrons within a longitudinal acceptance of $\Delta E/E = \pm 1\%$ divided by the number of electron on the target and by the primary beam energy.

Table 3
LIL performance for positron beam

LIL primary beam (e^-)		
Gun energy	80	keV
Buncher output energy	4	MeV
No-load energy at the target	200	MeV
$\Delta E/E$ (FWHH)	5.5	%
Transmission efficiency of :		
Bunching system	52	%
Linac	82	%
Beam sizes at the target (FWHH)	1.5	mm
Bunch length at the target (FWHH)	14	ps
Pulse length at the target (FWHH)	20	ns
LIL secondary beam (e^+)		
Energy	500	MeV
Positron current	11	mA
Unresolved yield (e^+/e^-)	7.54	10^{-3}
Resolved yield for $\Delta E/E = \pm 1\%$	5.9	10^{-3}
Normalised yield (e^+/e^-)(GeV)$^{-1}$	29.5	10^{-3}

5. CONCLUSION

From the beam dynamic simulations it has been possible to implement a new optics in LIL which allows a substantial increase in positron flux. The normalised yield increased from 0.024 to 0.0295. With this performance, it is possible to operate the LEP Pre-Injector machines with a safety factor of about three for LEP physics.

6. ACKNOWLEDGEMENT

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7. REFERENCES

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